Technology Opportunity

High Temperature Thin Film Strain Gauges

The NASA Glenn Research Center is actively developing high temperature thin film strain gauges which are miniature and deposited directly on the test articles. These sputter-deposited thin film resistance strain gauges can provide minimally intrusive surface strain measurements in the temperature range from ambient to at least 1100 °C.

Benefits

- Minimally intrusive. A complete sensor unit is only 20 μm thick compared to 200 μm of the conventional foil or wire strain gauge system.
- Very high temperature operation. Sensors extend the maximum use temperature from the current capability of 600 °C to at least 1100 °C.
- Versatile. Sensors can be designed for either dynamic or static strain measurements, can have various patterns and gauge resistance. Sensors can be fabricated directly on the test parts or can be on a metal shim which is then attached to the test articles.
- Highly stable and repeatable. The repeatability (between thermal cycles) of the sensors is within 200 microstrain (με) (25 to 1100 °C) compared to 1000 με (25 to 600 °C) of the conventional gauges. The drift strain is on the order of 200 με/hr @ 1100 °C compared to 100 με/hr @ 600 °C of the conventional gauges.
- Low cost. Sensors can be mass produced using IC-based device fabrication technology.

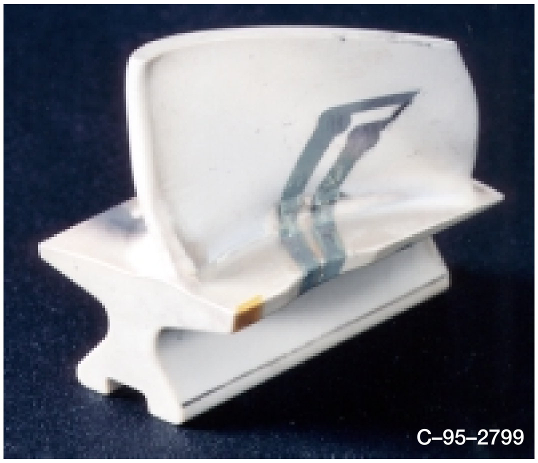
Potential Commercial Uses

These sensors will be extremely useful in the design and development of high speed civil transport vehicles and advanced gas turbine engines. They can be used for studying the crack development/propagation, residual stress, stress/strain distribution, and thermal expansion coefficient of materials at very high temperatures. These sensors can also be utilized and integrated as pressure transducers and high temperature extensometers. Any mechanical/structural design of new and advanced materials for applications in extremely high-temperature environments would benefit from the invention of these sensors.

These are the only known gauges that can measure surface strain with minimal intrusion and measure both dynamic and static strain to 1100 °C. No other gauge currently exists or is being marketed that can provide minimally intrusive strain measurement at such high temperatures with the accuracy and repeatability that these sensors offers.

The Technology

An electrical resistance strain gauge is a strain-sensing element whose electrical resistance changes in response to an applied strain. Knowing the strain sensitivity of the gauge, one can determine the applied strain from the change in gauge resistance. This type of strain gauge (normally foil or wire gauge bonded onto the surface of a test article with glue, ceramic cement, or flame-sprayed ceramic) is widely used at low temperatures because of its simplicity, high sensitivity, reliability, and low cost. As the operating temperature increases, however,



PdCr thin film strain gauge on a turbine blade.

the problems associated with this type of gauge also increase. At higher temperatures, the gauge materials currently in use experience either oxidation or structural changes. As a result, the characteristics of the gauge do not remain within acceptable limits over long periods of time, nor do they vary in a predictable manner. In addition, the bonding agents limit both the degree of strain transmitted from the test structure to the gauge and the maximum working temperature of the gauge. The bulky bonded gauge is also intrusive and thus disrupts the aerodynamic gas flow on the surface of the test structure.

In order to meet the urgent needs in aeronautic and aerospace research where stress and temperature gradients are high, aerodynamic effects need to be minimized, and higher operational temperatures are required, a thin film strain gauge has been developed at the NASA Glenn Research Center. This gauge, a vacuum-deposited thin film formed directly on the surface of a test structure, operates at much higher temperatures than do commercially available gauges.

The gauge uses an alloy, palladium-13 wt % chromium (hereafter, PdCr), which was developed by United Technologies Research Center under a NASA contract. This alloy is structurally stable and oxidation resistant up to at least 1100 °C; its temperature-induced resistance change is linear, repeatable, and not sensitive to the rates of heating and cooling. A strain gauge made of 25-µm-diameter PdCr wire was demonstrated to be useable to 800 °C, and won an R&D 100 award in 1991. By further improving the purity of the material and by developing gauge fabrication techniques utilizing sputter deposition, photolithography patterning, and chemical etching, we have made an 8- to 10-µm PdCr thin film strain gauge that can now measure dynamic and static strain to at least 1100 °C. For static strain measurements, a 5-µm-thick Pt element serves as a temperature compensator to further minimize the temperature effect of the gauge. These thin film gauges provide the advantage of minimally intrusive surface strain measurements and give highly repeatable readings with low drift at temperatures from ambient to 1100 °C. This is a 300 °C advance in operating temperature over the PdCr wire gauge and a 500 °C advance over the commercially available gauges made of other materials. This technology won an R&D 100 Award in 1995.

Options for Commercialization

One of NASA's missions is to commercialize its technology. The NASA Glenn Research Center's aim is to commercialize the thin film strain gauge technology described herein. The search for suitable materials for high-temperature static strain gauges has been underway since the introduction of the resistance strain gauge some 50 years ago. Until now, there has been no strain gauge system that has met all of the desired characteristics at high temperatures. This technology not only extends the maximum use temperature from the current capability of 600 °C to at least 1100 °C, but it also provides the advantage of making minimally intrusive surface strain measurements. This is a significant breakthrough that makes possible the testing/predictions of many advanced materials for use in harsh environments at extremely high temperatures.

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References

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